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# Production of White-Potato Starch

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Starch from white potatoes was first produced in the United States in 1831 in a plant at Antrim, N. H. The industry grew rapidly. By 1880, more than 150 factories were operating in Maine, New Hampshire, Vermont, Michigan, Wisconsin, Ohio, and Minnesota.

In some States, particularly Maine, varieties of potatoes were grown specifically for starch. They were not of high quality for cooking, but contained much more starch than the common varieties now grown. The practice of growing different types of potatoes for eating and for nonfood uses still is followed in the Netherlands and Germany.

Late in the nineteenth century the industry began to lose its strong position to cornstarch, which could be manufactured to sell at a lower price. Potato starch then became one of the specialty starches, which it still is.

Several points account for the lower cost of cornstarch. Although the acre yields of starch from potatoes and corn are comparable, corn is better adapted to mechanized methods of farming, which lower production costs. Corn dries out on the cob to a moisture content of 12 to 15 percent; in that condition it can be shelled, easily transported, and stored indefinitely before processing. Potatoes contain about 80 percent moisture, which means added bulk and weight in transportation, and they are so perishable that they require

special methods of storage. The ease of storage of corn has made it possible to build large factories, which can process the raw material throughout the year, but potato-starch factories operate ordinarily only about 8 months of the year, from October through May. Valuable byproducts in corn wet milling (oil and gluten feed, for example) aid materially in making the industry profitable. The potato-starch industry has no byproduct except the extracted pulp, which a few manufacturers recover and sell as feed.

The higher cost of making potato starch affected the industry greatly. By 1900 the number of potato-starch plants had fallen from more than 150 to 63. Moreover, the industry tended to be concentrated in Aroostook County, Maine; 45 of the 63 factories were there. Aroostook County became a center for production of table-stock and seed potatoes, and the starch industry provided an outlet for the culls. In 1920, the twenty-odd factories in Maine had a daily capacity of less than 75 tons of starch. In 1940, Aroostook County had 27 starch factories, whose total daily capacity was more than 150 tons of starch. This greatly increased capacity was due mainly to construction of three modern continuous-process plants in 1938 and 1939. Now, 20 potato-starch factories in Maine have a capacity of about 135 tons a day.

In 1941, two plants were built in Idaho—one at Blackfoot and one at Twin Falls. The Twin Falls plant was rebuilt on a larger scale in 1948. A third plant was built in 1942 at St. Anthony. Another was established at Menan in 1944, but was later moved to Idaho Falls. With the construction of another plant at Idaho Falls and conversion of a glucose-sirup plant at Jerome to starch manufacture in 1948, Idaho now has six potato-starch fac-

tories with a total capacity of about 140 tons a day. The country's total capacity for potato-starch production, therefore, is now approximately 275 tons a day, or 110 million pounds for a 200-day operating year. Because the industry uses cull and surplus potatoes, the supply of raw material is not constant, and the industry rarely if ever operates at capacity for as much as 200 days a year.

ABOUT 98 percent of the starch we produce is made from corn. Nearly two-thirds of the total cornstarch produced, however, is used for manufacture of glucose sirup, dextrose, and modified starches. About 90 percent of the starch used as such in the United States, or 1,389 million pounds a year, is cornstarch. The maximum production of the potato-starch industry is believed to be approximately 89 million pounds, attained in the 1946-47 season, when Maine produced an estimated 44 million pounds and Idaho 45 million pounds. The average production in recent years has been somewhat below that record.

Potato starch is used in industry in about the following percentages: Textiles, 30; foods, 20; paper, 20; dextrins, 15; confectionery, 5; and miscellaneous, 10.

The textile industry uses potato starch mainly in sizing cotton warps, but some also for sizing spun rayon and worsted warps. Potato-starch pastes revert slowly to the gel state upon cooling and thus penetrate better into the interstices of the warp than do pastes of some other starches. Better penetration results in a better anchored film, which protects the warp from abrasion in the loom. Potato starch is outstanding in the strength it imparts to paper in beater sizing. Potato dextrins give relatively flexible films, which resist checking and remoisten readily.

The Eastern Regional Research Laboratory has undertaken studies to compare the physical and chemical properties of potato starch with those of other commercial starches. The aim is

to find new uses for potato starch. Since 1944, various techniques and specialized equipment have been employed there in the search for ways in which potato starch is unique among starches.

THE SIZE, STRUCTURE, AND SHAPE of the starch granules have undergone scrutiny by technicians using the optical microscope. The molecular arrangement has been studied in detail by X-ray specialists. The structure of the granules has been further explored with the electron microscope. The molecular weight of potato-starch fractions have been determined with specially designed light-scattering equipment.

Factors influencing the paste consistency and gel firmness of potato starch have been investigated at length. Although it has long been known that the presence of calcium lowers the consistency of pastes, workers in the Eastern Laboratory found that even traces of calcium have a pronounced effect. So sensitive is the paste consistency to minute amounts of calcium that changes in the hardness of processing water from season to season result in changes in the final product, previously unexplained.

Little by little the fundamental causes for the unique properties of potato starch—its large granule size, its relatively high molecular weight, and the peculiar packing of matter in its molecule—are being unfolded. Research on technical applications will follow the fundamental studies. The largest potential fields of expansion appear to be in the paper and food industries.

Apparently it is not economical now for American farmers to grow potatoes just for industrial use. Starch manufacture, however, is to be regarded as an integral part of a well-organized potato industry, which markets its best potatoes for eating and processes the substandard grades. Marketing agreements in the potato industry are leading to these practices now more than

ever before. Starch factories provide an outlet for potatoes that should be kept off the food market in order to make effective the slogan, "Sell the best—and process the rest." The higher price that the public will pay for uniformly high-quality potatoes should make it possible to place a lower value on sub-standard potatoes diverted to industrial processing.

IN OUR MORE MODERN potato-starch factories, the operations are essentially continuous. A typical Maine factory can produce about 10 tons of starch in a 24-hour day, for which it will use 80 to 90 tons of potatoes. An analysis of the potatoes processed shows these components, in percentages: Starch 13; protein, 2; cellulosic material, 1.5; sugars, 0.5; mineral (ash), 1; miscellaneous minor constituents, 1; water, 81. (Potatoes received by the Idaho starch plants average 15 or 16 percent starch.)

Storage facilities in the factory can handle as much as 4,000 barrels, each weighing 165 pounds, of potatoes.

A description of the process used by one of the modern plants is given here, but we must stress that the equipment and methods used in other modern factories may differ in some respects from the one we describe.

The potatoes to be processed are removed from storage by a flume to a conveyor, which dumps them into a washing trough where they are tumbled in water to free them of dirt. The potatoes are then elevated to a hopper and metered through a screw conveyor to a rasp, which reduces them to a slurry. The slurry is diluted with water containing sulfur dioxide and is pumped to a screening battery, in which most of the cellulosic material, or pulp, is separated from the starch granules. The screening battery has a series of screens and sieves, one mounted above the other in this order: Shaker screen, bottom rotary brush sieve, top shaker screen, and top rotary brush sieve.

The potato slurry from the rasp is pumped onto the bottom sieve, which

has perforated holes 0.03 inch in diameter. Here the starch milk (principally starch granules suspended in water) passes through, and the pulp discharges over the end of the sieve. The pulp is diluted with water and passes into an attrition—or disc—mill for further grinding-rubbing to release more starch. The mill has two carbondrum-type plates mounted closely together, one of which rotates. The starch milk, along with finely divided pulp from the bottom sieve, falls onto the bottom 80-mesh shaker screen. The starch milk runs through, and most of the fine pulp drops off the end of the screen and is combined with the re-ground pulp from the attrition mill. The combined pulp is pumped to the top sieve (which has perforated holes 0.02 inch in diameter) and is washed with a spray of water. The fine pulp and starch milk pass through the sieve and drop onto the top 100-mesh shaker screen. The starch milk continues through to the bottom shaker screen, and the fine pulp from the top shaker screen and the coarse pulp from the top sieve combine and are discharged to the sewer.

The starch milk from the screening battery—that is, the starch milk through the bottom shaker screen—goes to a continuous centrifuge, where the protein water is removed from the starch and discarded to the sewer. The protein water contains about 1 percent total solids, which comprise mainly soluble protein, with some fine starch and fine pulp. The starch from the separator is diluted with water and pumped to a 120-mesh shaker screen, where more fine pulp is removed. The starch milk then passes to starch tables for final purification. At that stage, the starch settles on the tables, and any residual fine pulp passes off the end. The tables are about 40 feet long, with a slope of about one-thirty-second inch to the foot. They fill up in about 4 hours. The starch cake from the tables is shoveled into a conveyor, where it is diluted with water; then it flows into a storage tank or pit. The density of the

starch milk is adjusted in a make-up tank. Then the milk is fed to a continuous rotary vacuum filter, which dewaters the starch to about 40 percent moisture and delivers it as a broken cake to a continuous-belt, hot-air drier. The pieces of starch cake, dried to a moisture content of about 16 percent, are transferred to a pulverizer, where they are reduced to a powder. The starch is loaded into 200-pound, kraft-lined burlap bags.

The finished starch typically has the following composition in percentages on a moisture-free basis: Starch, 98; ash, 0.3; and cold-water solubles, 0.1. It has traces of nitrogen and sugars.

THE DISPOSAL OF WASTE MATERIALS from starch factories remains a problem. It is becoming more acute, particularly since Federal and State regulations on stream pollution have become more stringent. A factory that produces 10 tons of starch a day discharges about 4,500 pounds of waste pulp solids and 6,500 pounds of protein water solids during that period. The pulp contains about 4 percent solids.

Analysis of a sample of dried waste pulp showed the following percentage composition: Moisture, 4.5; starch, 54.6; uronic acid anhydride, 16; pectin, 12; pentosans, 9.5; crude fiber, 15.6; ash, 1.0; fat, 0.4; protein, 5.9; sugars, a trace. (The total is more than 100 percent, probably because of overlapping in the uronic acid anhydride, pectin, and pentosan determinations.)

The following procedure is suggested for recovery of the waste pulp; it is based on experience in recovering pulp from 2 million pounds of potatoes and on German technical processes:

The pulp would first be discharged into a tank and mixed with lime. The limed pulp would be partly dewatered on a vibrating screen; further dewatered by passage through continuous rotary presses, and then dried in a steam-tube rotary drier.

Wet waste potato pulp is frequently used as hog feed in Europe, and has

been so used in the United States. The dried pulp has also been fed to livestock, usually mixed with a high-protein feed.

The protein water from a potato-starch factory contains about 1 percent total solids—about 0.6 percent protein, 0.1 percent starch, and the remainder principally fiber and sugars. No economical method is known for recovery of the solids from protein water because of the great dilution.

R. K. Eskew, of the Eastern Laboratory, made a survey of potato-starch processing in Europe in the summer of 1947. He reported that protein is recovered in starch factories, particularly in Germany, by diluting the potato slurry, immediately after the initial grinding, and passing it through a Jahn or Uhland continuous centrifugal separator to recover the protein solution in more concentrated form than ordinary "protein water." The protein is then coagulated by heat or chemicals, dewatered, and dried. Protein water is also reported to have been concentrated under vacuum at 113° F. to 48 percent solids and then dried in admixture with dewatered pulp. During periods of protein shortage, potato protein has been recovered in Germany for enrichment of soups.

Apparently an economical method, used in some European countries, for preventing stream contamination with waste protein water is to spray the effluent on fields after the potatoes have been harvested. Some benefit is gained through action of the effluent water as a fertilizer.

A PILOT PLANT has been set up in the Eastern Laboratory for studying the technology of manufacturing white-potato starch in order to develop practical methods of improving quality, increasing starch yields, simplifying operations, and recovering waste materials. To provide a background for planning the plant, we studied processing operations in the factories in Maine and Idaho.

We have not had time to study com-

pletely the operations and make recommendations for best processing methods. Grinding the potatoes is one operation that we began to study in 1950. We are experimenting with several types of grinding machines to determine which will release the most starch without excessive power consumption and excessive production of fine pulp. The fine pulp is objectionable, because it goes through the screens with the starch milk during subsequent screening operations, making purification of the milk more difficult.

Preliminary experiments have shown that a vertical-type hammer mill is about equivalent to a rasp in releasing starch. If this is confirmed in further experiments, it will be advantageous—the hammer mill is commercially available, whereas the rasp is not. (Some of the starch factories now use vertical-type hammer mills.)

In current operations, about 10 percent of the starch present in the potato remains in the waste pulp, because it has not been freed in the grinding. On the dry basis, the starch ordinarily constitutes about 45 percent of the weight of the waste pulp. We will try to reduce the amount of starch that goes to waste by further study of the grinding operations.

Screening is another important operation in the starch process under investigation. Experiments have shown that the purity of the starch milk at that stage is appreciably improved by using finer mesh screens for separating the pulp than are now generally used.

These are only two of the phases of starch manufacturing under investigation. Other studies are planned. One

has to do with the recovery of waste materials. Even though the potato-starch industry is old, we believe that opportunities exist for improving the engineering aspects of the processing. Because it is an industry of many small manufacturers, the companies themselves have not had adequate technical staffs to undertake such research and development. By thorough modernization along lines that will give high-quality starch in maximum yield, the starch manufacturer should continue to serve as an important adjunct to the table-stock potato industry and to supply consumers who demand the special properties of potato starch.

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